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C1Or3A-03: Further experimental work in mixed-gas Joule-Thomson cryocooling

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Miniature Joule-Thomson (JT) cryocoolers are attractive for many applications due to their small size and resulting fast cool-down time. Finned-tube heat exchangers are the most widely used heat exchanger for miniature JT cryocoolers. The basic configuration, known as a Giauque-Hampson (GH) or coiled tube heat exchanger, involves the high-pressure stream flowing through a finned-tube that is helically coiled upon a cylindrical core while the low-pressure return stream flows over the fins in the annular space created by the core and the inner diameter of a shell. While it has been suggested that the heat transfer coefficient (htc) of the return stream is a key parameter affecting the behavior of the entire GH heat exchanger for a mixed-gas Joule-Thomson (MGJT) cryocooler, there is still no data or theory in open literature that characterizes the heat transfer and pressure drop characteristics of two-phase multi-component mixtures on the shell side in these heat exchangers.

The experimental work in this study aimed to gain insight into these thermal characteristics by developing a test facility capable of measuring the two-phase htc for this geometry at operating conditions of interest to MGJT cryocooling. The capabilities of the test facility were demonstrated. The size of the GH heat exchanger prototype and operating parameters of the test facility were consistent with those of interest for MGJT cryocoolers. Measurements of the two-phase htc of the mixed gas on the shell-side of the GH heat exchanger prototype were collected. For the mixture examined, the two-phase htc was found to be between 12 to 19 W/m2-K with uncertainties of approximately 12% for qualities in the range of 0.31 to 0.62. This data reveals that the shell side is the dominant thermal resistance for these operating conditions, even though the fins provide a larger surface area. Therefore, the htc of the mixed gas on the shell-side is crucial for cryocooler design and predicting the overall performance. The data collected clearly demonstrates the need for and importance of developing accurate correlations for two-phase multi-component mixtures on the shell-side of GH heat exchangers for operating conditions consistent with MGJT cryocoolers. Only with these correlations can the effects of the mixture selection on the pressure drop and the effectiveness of the heat exchanger be considered in the design of a MGJT cryocooler for optimal performance.

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